

Software Reliability Analysis Tools

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Outline

- Background
- MATLAB Automated Testing Tool
- Graphical Input Specification Tool
- Real-Time Analysis Testing Tool
- Status
- Conclusion

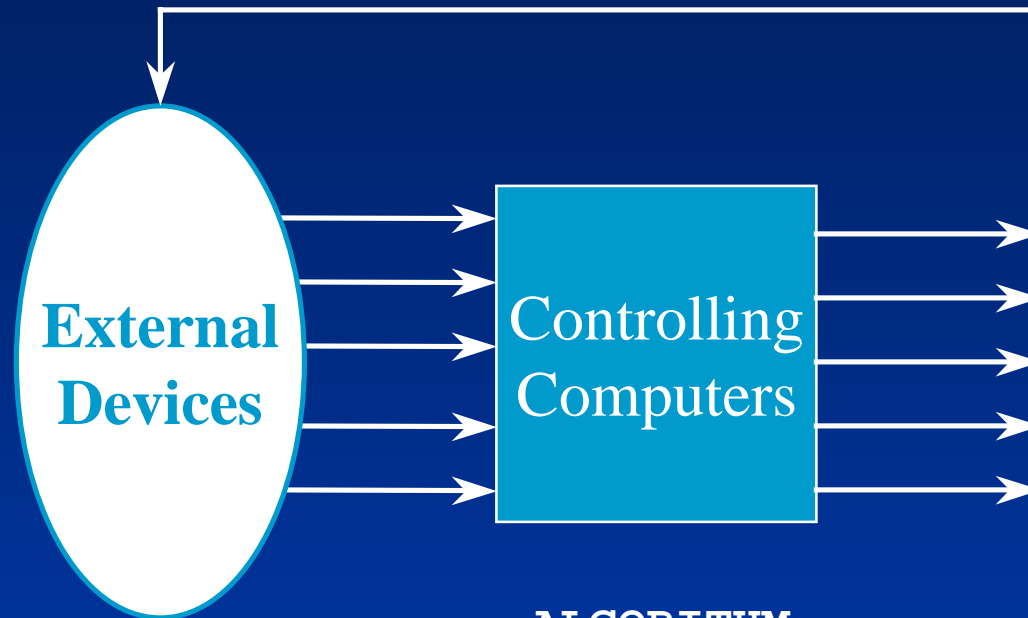
System Development

Example: Wind Tunnel Software

- Controls devices that control:
 - Wind generator
 - Model support
 - Tunnel atmosphere
- Emphasizes reliability and safety
- Utilizes multiple development strategies
- Based on simple structure

System Development

Simple Structure



ALGORITHM

Sample Inputs

Run Software

Update Outputs

Testing Problems

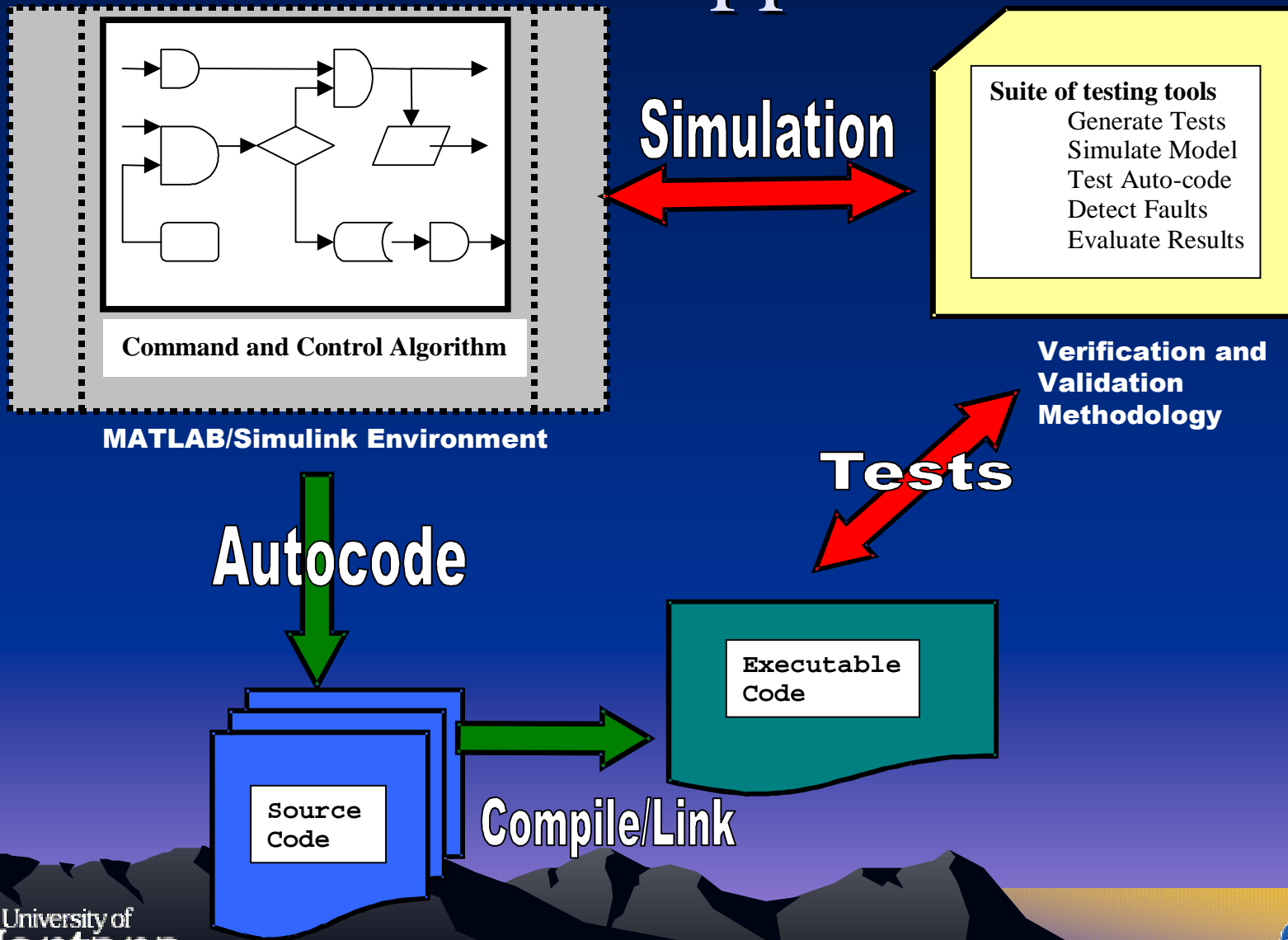
- Size
 - Input variables – sampled over time
 - Outputs variables – produced over time
 - Sample time – variable or set frequency
- Requirements
 - Input file/matrix
 - Output file/matrix
 - Analysis tools
- Domain determinants
 - Input variable – minimum, maximum, and accuracy
 - Output variable – minimum, maximum, and accuracy
- Test requirements
 - Input file/matrix with all possible values for input
 - Output file/matrix much more complex problem

Solution Approach

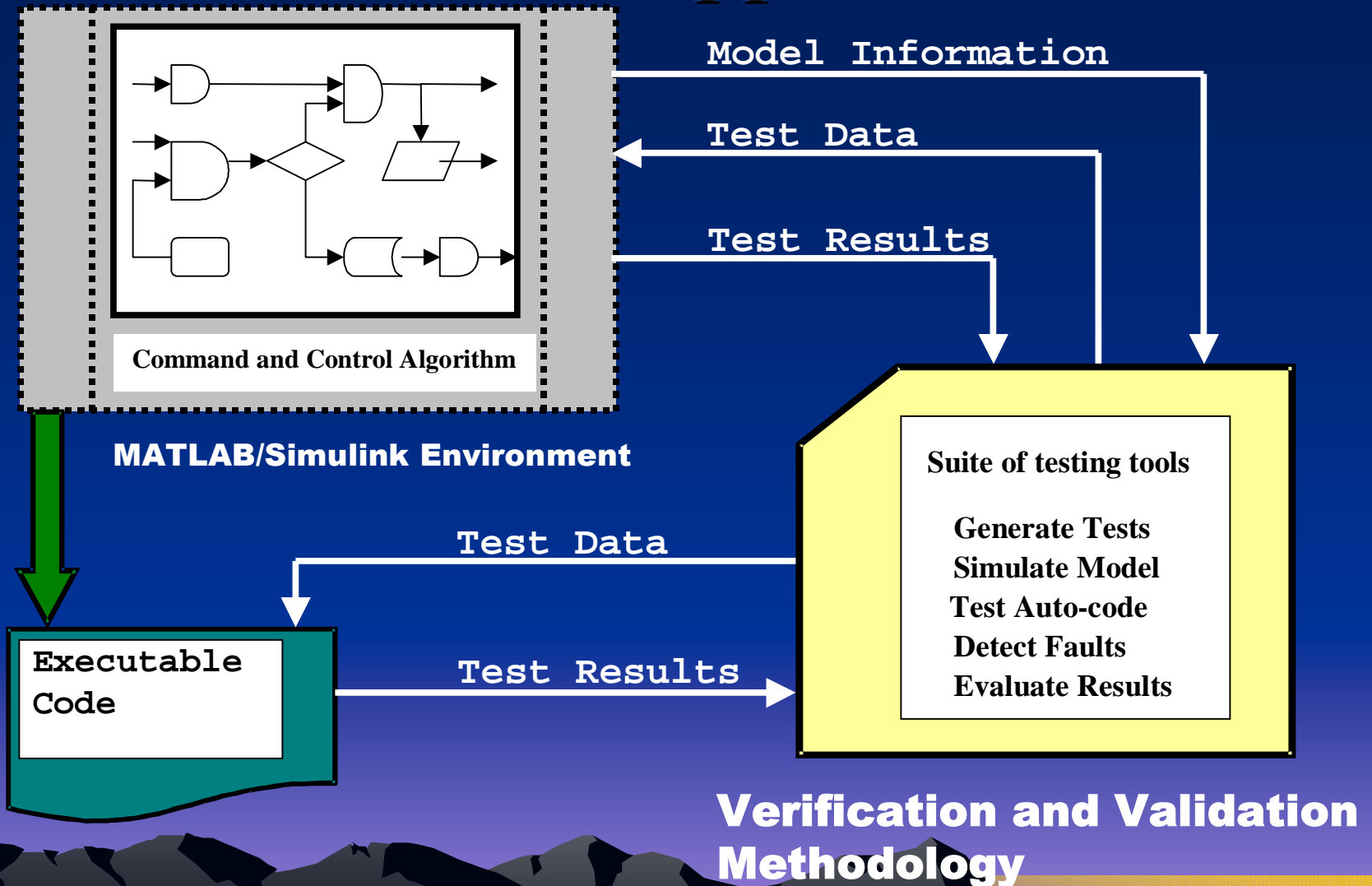
Overview

- Automation to:
 - Generate large input matrices/files
 - Perform simulation and/or test auto-generated code
 - Analyze output matrices/files
- Methods to:
 - Evaluate domain coverage
 - Aid debugging
 - Evaluate results

Solution Approach



Solution Approach



MATLAB Automated Testing Tool

- Creates test data
- Executes simulation or test
- Captures results
- Detects exceptions
- Saves test data or complete test results

MATT – Test Setup

Inputs

Select System:

Inputs | States | Outputs | SimResults | Adv. Exceptions | Parameters

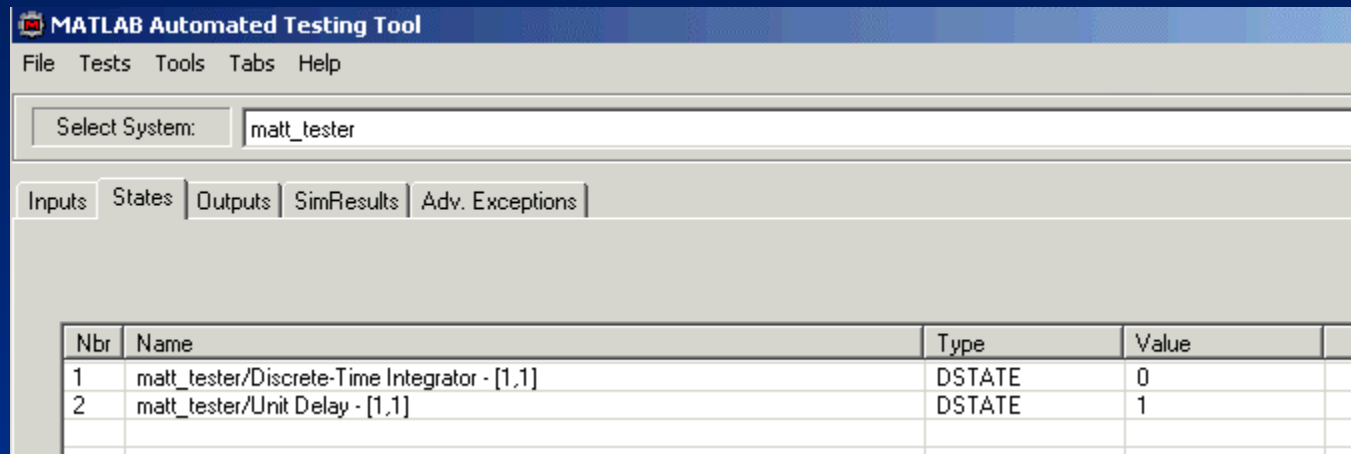
Start: sec. Stop: sec. Total: sec. Max Step Size: sec. Total Steps:

Nbr	Input Label	Type	Minimum	Maximum	Accuracy	Test	Constant	Test Minimum	Test Maximum
1	u1 - [1,1]	double	-1.797693134E+298	1.797693134E+298	2	Min2Max	0	0	500
2	u2 - [1,1]	double	-1.797693134E+298	1.797693134E+298	2	Min2Max	0	0	500
3	u3 - [1,1]	double	-1.797693134E+298	1.797693134E+298	2	RDMax	0	0	500
4	u4 - [1,1]	double	-1.797693134E+298	1.797693134E+298	2	RA2Max	0	0	500

- Set test running time
- Select and configure tests using 31 test types
- Now supports non-scalar inputs*

MATT – Test Setup

States



MATLAB Automated Testing Tool

File Tests Tools Tabs Help

Select System: matt_tester

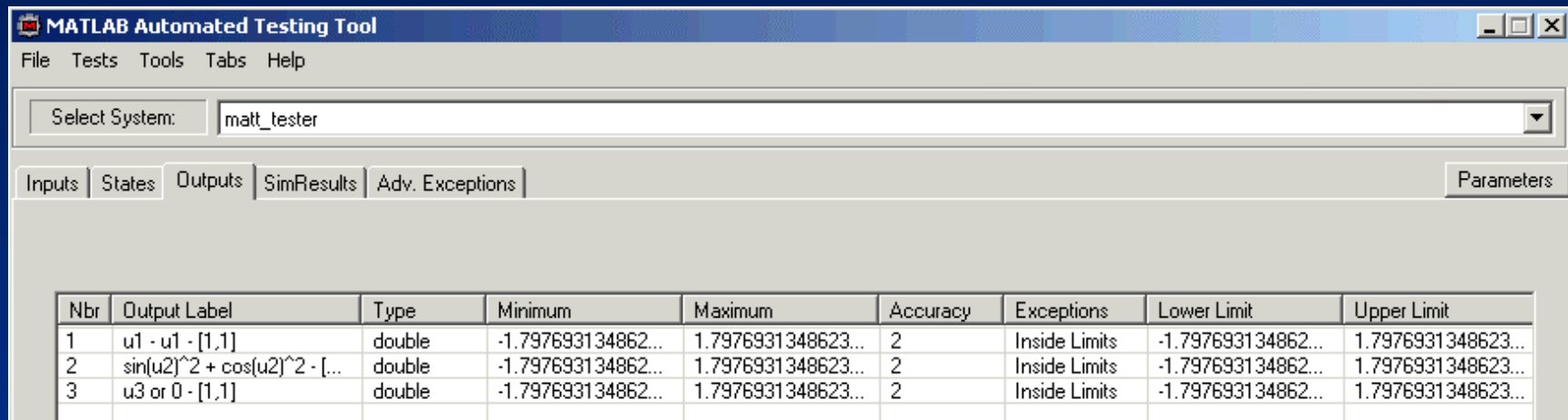
Inputs States Outputs SimResults Adv. Exceptions

Nbr	Name	Type	Value
1	matt_tester/Discrete-Time Integrator - [1,1]	DSTATE	0
2	matt_tester/Unit Delay - [1,1]	DSTATE	1

- Assign Starting values for state blocks*

MATT – Test Setup

Outputs



Nbr	Output Label	Type	Minimum	Maximum	Accuracy	Exceptions	Lower Limit	Upper Limit
1	$u1 - u1 - [1,1]$	double	-1.797693134862...	1.7976931348623...	2	Inside Limits	-1.797693134862...	1.7976931348623...
2	$\sin(u2)^2 + \cos(u2)^2 - [...]$	double	-1.797693134862...	1.7976931348623...	2	Inside Limits	-1.797693134862...	1.7976931348623...
3	$u3$ or $0 - [1,1]$	double	-1.797693134862...	1.7976931348623...	2	Inside Limits	-1.797693134862...	1.7976931348623...

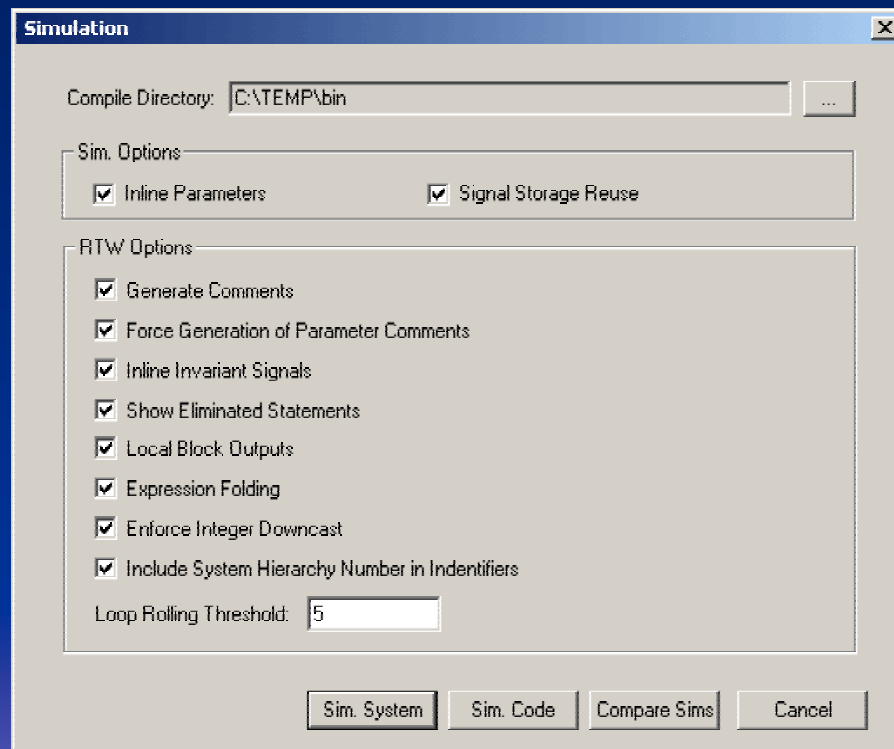
- Set output accuracy and exception ranges
- Now supports non-scalar outputs*

MATT – Test Setup

New Exception Types

- Percent change*
 - Allows exception detection if the output value changes more than a specified percent over a specified number of steps
- Absolute change*
 - Allows exception detection if the output value changes more than a specified amount over a specified number of steps

MATT – Simulate



- Set up simulation and code generation options
- Simulate:
 - Model
 - Auto-generated Code
 - Compare both

MATT – View Results

MATLAB Automated Testing Tool

Select System: matt_tester

Inputs | States | Outputs | **SimResults** | Adv. Exceptions | Parameters

Input Label	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	Test 16	Test 17	Test 18
u1 - [1,1]	40	45	50	55	60	65	70	75	80	85
u2 - [1,1]	40	45	50	55	60	65	70	75	80	85
u3 - [1,1]	0.5	0.64	0.79	0.95	1.13	1.33	1.54	1.77	2.01	2.27
u4 - [1,1]	172.53	194.58	108.22	202.17	83.93	168.51	225.03	80.05	136.33	245.97

Pan Test Interval: < > Total: 101

Output Label	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	Test 16	Test 17	Test 18
u1 - u1 - [1,1]	0	0	0	0	0	0	0	0	0	0
sin(u2)^2 + cos(u2)^2 - ...	1	1	1	1	1	1	1	1	1	1
u3 or 0 - [1,1]	0.13	0.13	0.79	0.79	0.79	0.79	0.79	0.79	2.01	2.01

Nbr	Output Label	Type	Accuracy	Exceptions	Lower Limit	Upper Limit	Total Exce...	Actual Min.	Actual Max.	Average
1	u1 - u1 - [1,1]	double	4	Inside Limits	-1.79769E+308	1.79769E+308	101	0	0	0
2	sin(u2)^2 + co...	double	4	None	-1.79769E+308	1.79769E+308	0	0	1	0.9901
3	u3 or 0 - [1,1]	double	4	Inside Limits	0.5	2	6	0	71.81	23.8775

- View input values for every time-step
- View output values for every time-step
 - Steps causing exceptions are highlighted red*
- View/edit output exception info and settings

MATT – Advanced Exceptions*

- Advanced Exceptions allow exception detection based on multiple exception criteria
 - A combination of output ports
 - Disjoint ranges
 - Create separate A.E definition for each range that needs to be tested
 - Do a combinational process based on all the A.E definitions
 - Overall system reliability
 - Create multiple A.E definitions based on system specifications
 - Perform a combinational process based on all the defined Advanced Exceptions

MATT – Advanced Exceptions

Combination of output ports

- In the example shown below, an exception is said to have occurred when:
 - Stick output is between 5 and 10
 - Alpha output is greater than 20 rads
- After clicking the *process* button, one discovers:
 - 7 exceptions occurred from the given exception definition
 - The time steps where the 7 exceptions occurred
 - The output values that produced the 7 exceptions

The screenshot shows the 'Adv. Exceptions' tab in the MATT software. The 'Definition Name' is 'AdvDefn_1' and the 'Number of Exceptions' is 7. The 'Exception Time Steps' list shows 20, 27, and 30. The 'Time Step Window' shows 'Start: 1' and 'Stop: 601'. The 'Process' button is highlighted. Below the definition, a table lists the exceptions:

Nbr	Output Label	Exceptions	Lower Limit	Upper Limit
1	alpha (rad) - [1,1]	Above Limit	0	20
2	Nz Pilot (g) - [1,1]	None	-1.79769313486232E+308	1.79769313486232E+308
3	Stick Input Display - [1...	Inside Limits	5	10

Below the table, the 'Pan Output Interval' is set to 1. The 'Total' is 601. A table at the bottom shows the output values for the 7 exceptions:

Nbr	Output Label	Time 30	Time 31	Time 32	Time 33	Time 34	Time 35	Time 36	Time 37	Time 38
1	alpha (rad) - [1,1]	22.1014	20.557	19.4497	19.7266	21.7357	24.8921	27.4962	28.0924	26.9073
2	Nz Pilot (g) - [1,1]	260.8642	268.4321	369.9053	495.811	500.7782	379.5698	126.4136	34.1538	135.0069
3	Stick Input Display - [1...	8.7591	29.1598	47.4837	50.8072	51.6419	11.5818	6.4125	9.7707	6.1775

MATT – Advanced Exceptions

Disjoint Ranges

- In this example, two separate exception definitions are specified:
 - (1) Alpha producing values between 0 - 4 rads
 - (2) Alpha producing values between 15 – 19 rads
- These two exception definitions are combined, and exception results are calculated in aggregate.

Parameter:										
Definition Name: Combination Number of Exceptions: 6 Add Remove Process Exception Time Steps Time Step Window Start: 1 Stop: 601										
Nbr	Output Label	Exceptions	Lower Limit	Upper Limit						
<input checked="" type="checkbox"/>	AdvDefn_1									
1	alpha (rad) - [1,1]	Inside Limits	0	4						
2	Nz Pilot (g) - [1,1]	None	-1.79769313486232E+308	1.79769313486232E+308						
3	Stick Input Display - [1...	None	0	0						
<input checked="" type="checkbox"/>	AdvDefn_2									
1	alpha (rad) - [1,1]	Inside Limits	15	19						
2	Nz Pilot (g) - [1,1]	None	-1.79769313486232E+308	1.79769313486232E+308						
3	Stick Input Display - [1...	None	-1.79769313486232E+308	1.79769313486232E+308						
Pan Output Interval << < > >> Total: 601										
Nbr	Output Label	Time 1	Time 2	Time 3	Time 4	Time 5	Time 6	Time 7	Time 8	Time 9
1	alpha (rad) - [1,1]	0	0.2835	1.8696	4.5481	8.0491	12.1645	15.8209	18.5304	20.2797
2	Nz Pilot (g) - [1,1]	0	113.9487	239.2529	176.5641	224.2965	177.7162	68.8046	90.567	141.5162
3	Stick Input Display - [1...	33.4035	30.5925	17.2017	49.0951	31.8794	17.9828	28.6226	10.1022	49.4363
Excep. causing defns:		1	1	1				2	2	

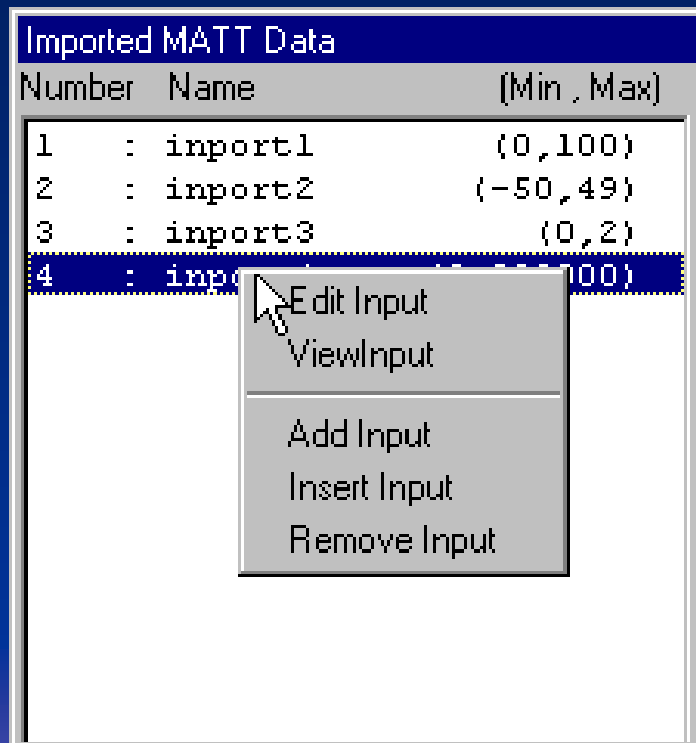
MATT - Storage

- Save complete test setup for future use
 - Input, State, and Output settings
 - Advanced Exception Setting
 - Input Matrix
 - Output Matrix
- Import and export custom input matrices
 - Comma delimited files (*.csv)
 - MATLAB data files (*.mat)

GIST

- Reads MATT test data files
- Allows freehand specification of test data
- Saves new MATT test data files

GIST – Manage Input Sets

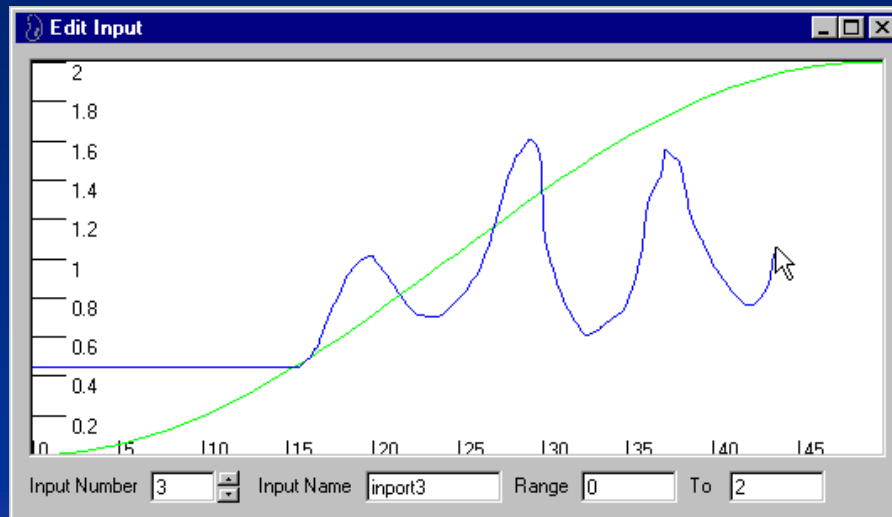


Number	Name	(Min, Max)
1	: inport1	(0,100)
2	: inport2	(-50,49)
3	: inport3	(0,2)
4	: inport4	(0,100)

- Add/Remove inputs for altered models
- View graphs of any input
- Edit any input

GIST – Edit Inputs

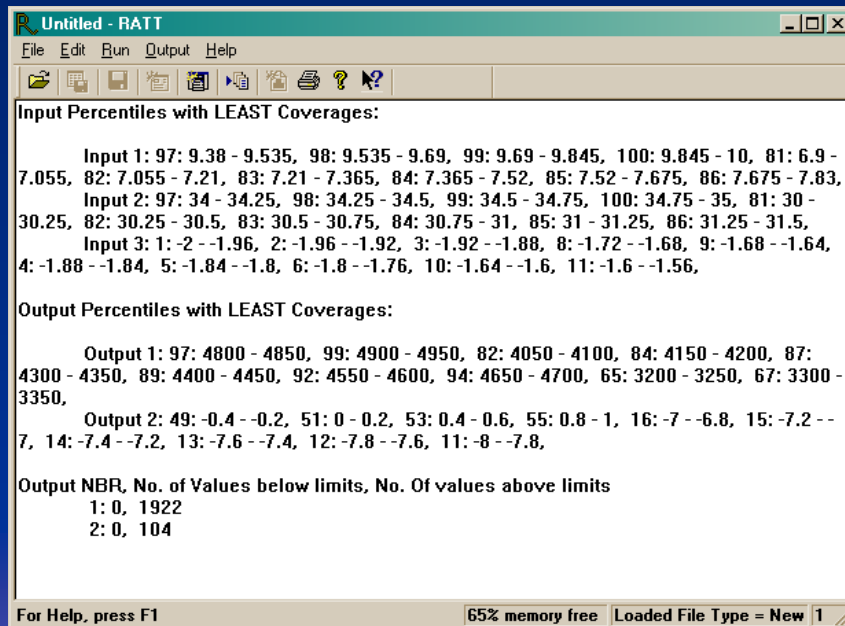
- Use simple click and drag to create new input values
- View original input values as drawing



RATT

- Reads MATT test result files
- Calculates reliability, probabilities, and completeness measures
- Supports analysis of multiple test files (test suite)
- Exports to MS Excel and populates analysis charts and graphs

RATT - Analysis



The screenshot shows the RATT software window titled 'Untitled - RATT'. It has a menu bar with 'File', 'Edit', 'Run', 'Output', and 'Help'. Below the menu is a toolbar with various icons. The main text area displays the following results:

```
Input Percentiles with LEAST Coverages:
    Input 1: 97: 9.38 - 9.535, 98: 9.535 - 9.69, 99: 9.69 - 9.845, 100: 9.845 - 10, 81: 6.9 - 7.055, 82: 7.055 - 7.21, 83: 7.21 - 7.365, 84: 7.365 - 7.52, 85: 7.52 - 7.675, 86: 7.675 - 7.83,
    Input 2: 97: 34 - 34.25, 98: 34.25 - 34.5, 99: 34.5 - 34.75, 100: 34.75 - 35, 81: 30 - 30.25, 82: 30.25 - 30.5, 83: 30.5 - 30.75, 84: 30.75 - 31, 85: 31 - 31.25, 86: 31.25 - 31.5,
    Input 3: 1: -2 - -1.96, 2: -1.96 - -1.92, 3: -1.92 - -1.88, 8: -1.72 - -1.68, 9: -1.68 - -1.64, 4: -1.88 - -1.84, 5: -1.84 - -1.8, 6: -1.8 - -1.76, 10: -1.64 - -1.6, 11: -1.6 - -1.56,

Output Percentiles with LEAST Coverages:
    Output 1: 97: 4800 - 4850, 99: 4900 - 4950, 82: 4050 - 4100, 84: 4150 - 4200, 87: 4300 - 4350, 89: 4400 - 4450, 92: 4550 - 4600, 94: 4650 - 4700, 65: 3200 - 3250, 67: 3300 - 3350,
    Output 2: 49: 0.4 - 0.2, 51: 0 - 0.2, 53: 0.4 - 0.6, 55: 0.8 - 1, 16: -7 - -6.8, 15: -7.2 - -7, 14: -7.4 - -7.2, 13: -7.6 - -7.4, 12: -7.8 - -7.6, 11: -8 - -7.8,

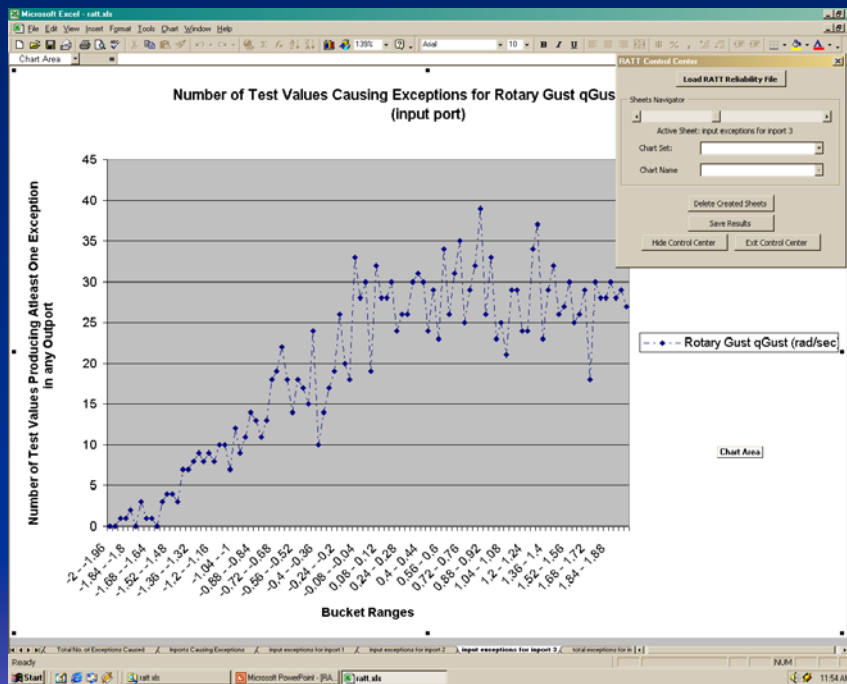
Output NBR, No. of Values below limits, No. Of values above limits
    1: 0, 1922
    2: 0, 104

For Help, press F1      65% memory free   Loaded File Type = New 1
```

- Load several MATT test files at once
- Perform analysis
 - Input coverage
 - Output coverage
 - MTTF
 - Probability of failure
 - Etc
- View simple results in RATT

RATT – Excel® Tool

- Load RATT files into Excel®
- View graphs showing coverage
- View coverage on multiple inputs/exceptions at the same time



Current Status

- Windows and UNIX versions of MATT ready
- Windows versions of GIST and RATT ready
- Working with STEREO project
 - Testing MATLAB/Simulink® models using MATT

Upcoming Functionality

■ MATT

- View intermediate state values from simulation
- Create and use custom test-types
- Load models inside MATT
 - Allows MATT to launch outside of MATLAB®

■ GIST

- Being integrated into MATT for more seamless use

■ RATT

- Being revised to accommodate Advanced Exceptions

Conclusion – Testing Enhanced

- Using software tools to aid testing allows
 - More tests to be run
 - Each test to be run more quickly
 - Test results to be easily stored and referenced

Conclusion – Tools Enhanced

- Improved MATT capabilities allow
 - Systems to start at any state with ease
 - More advanced exception catching

Questions and Contact Info

- Joel Henry
 - henryj@cs.umt.edu
 - MATT, RATT, and GIST
 - <http://www.cs.umt.edu/RTSL/matt/>
- MATLAB and Simulink users

